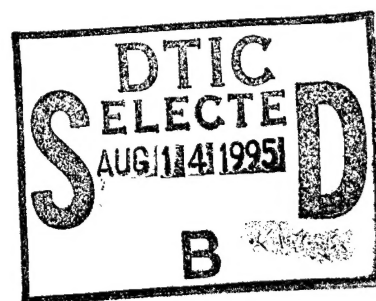


NAVAL POSTGRADUATE SCHOOL MONTEREY, CALIFORNIA



THESIS

**AN ANALYSIS OF THE
TOTAL QUALITY MANAGEMENT
PRACTICES OF THE
CONTRACTORS SUPPORTING THE
APACHE HELICOPTER PROGRAM**

by

Anthony S. Pelczynski

March, 1995

Principal Advisor:
Associate Advisor:

Mark Stone
Keith Snider

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE March 1995	3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE AN ANALYSIS OF THE TOTAL QUALITY MANAGEMENT PRACTICES OF THE CONTRACTORS SUPPORTING THE APACHE HELICOPTER PROGRAM			5. FUNDING NUMBERS	
6. AUTHOR Anthony S. Pelczynski				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) PEO, Aviation, 4300 Goodfellow Blvd, St. Louis, MO 63120-1798			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT This thesis study explores the Total Quality Management (TQM) practices of the prime contractors and subtier contractors supporting the Apache Helicopter Program. The Apache Helicopter Product Manager is searching for ways to lower costs and improve the quality and reliability of his product over the long-term. The Apache Helicopter, with the Longbow upgrade, is projected to remain in service to the year 2045. The defense contractors and subcontractors supporting the Apache Helicopter Program must adopt a business operating philosophy that fosters continuous process and quality improvement. Total Quality Management has become the management philosophy of choice. The subtier suppliers and vendors play an important role in the quality improvement capability of the prime contractors. The subtier contractors must also have the ability to continuously improve their process capabilities. This study intends to discover what can be done, if anything, to get the subtier contractors to adopt the management philosophy of TQM.				
14. SUBJECT TERMS Total Quality Management, Apache Longbow Helicopter, Subcontractor Management.			15. NUMBER OF PAGES 81	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18 298-102

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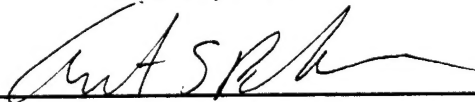
Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

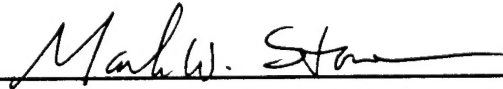
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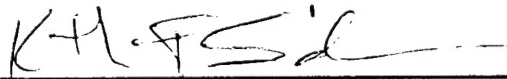


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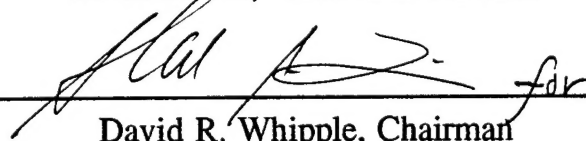
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ABSTRACT

This thesis study explores the Total Quality Management (TQM) practices of the prime contractors and subtier contractors supporting the Apache Helicopter Program. The Apache Helicopter Product Manager is searching for ways to lower costs and improve the quality and reliability of his product over the long-term. The Apache Helicopter, with the Longbow upgrade, is projected to remain in service to the year 2045. The defense contractors and subcontractors supporting the Apache Helicopter Program must adopt a business operating philosophy that fosters continuous process and quality improvement. Total Quality Management has become the management philosophy of choice. The subtier suppliers and vendors play an important role in the quality improvement capability of the prime contractors. The subtier contractors must also have the ability to continuously improve their process capabilities. This study intends to discover what can be done, if anything, to get the subtier contractors to adopt the management philosophy of TQM.

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ACKNOWLEDGEMENT

The author would like to acknowledge the support of the Program Executive Office, Aviation, and particularly, Lieutenant Colonel Richard R. Ryles for his assistance throughout the thesis writing process.

The author would also like to thank Professor Stone and LTC Snider for their guidance and patience throughout the thesis process.

The author would also like to express appreciation to Mr. Erik Houts, Quality Improvement Process Manager for Kaiser Electronics for the time and effort he extended during the initial phase of the thesis process.

I. INTRODUCTION

A. PURPOSE

The Department of Defense (DOD) has placed an increased emphasis on quality in all major acquisition programs. Significant budget cuts and weapon systems program reductions have forced DOD to focus on quality and to contract using best value criteria. As a result, the U.S. defense industry has become extremely competitive. Defense companies must compete for fewer defense dollars, not only in the domestic market, but globally as well. [Ref. 35]

To be competitive in today's market requires a company to retain current business and gain new contracts. They can do so by being responsive to the customers, staying current with technology, and producing a quality product. Through these actions the company can meet its obligation to the stakeholders, the employees, the suppliers, and the stockholders and investors. To accomplish these ends, many companies have adopted Total Quality Management (TQM) as their business operating environment. [Ref. 33]

The Apache Helicopter Program has remained viable in this era of defense downsizing. The program is supported by many hundreds of small to large companies. The Apache helicopter, with the Longbow upgrade, has been projected to remain in service beyond the year 2045 [Ref. 38]. In order for this program to survive future program cuts and remain viable, the cost of maintaining and supporting the system must decrease and the quality of the system must improve.

The Apache Helicopter Product Manager has adopted TQM as his business operating philosophy [Ref. 38]. This philosophy requires cross-functional teamwork and continuous quality improvement with suppliers and customers alike. The Product Manager (PM) and the contractors must work together to continuously improve the system and the processes used to make

the product. As the quality improves, costs will decrease by reducing waste and non-value-added elements to the process, improving cycle-time, and reducing the need for extensive sampling and testing.

Yet, many companies that produce critical components for the Apache helicopter still have not adopted a practice of continuous quality improvement. Adopting such a practice requires an unbending commitment to quality, a thorough plan to guide the company to its goals and objectives, and financial investment. Creating an effective quality management environment is a slow, arduous process. Winners of the Malcolm Baldrige National Quality Award (MBNQA) have taken up to six years to establish a suitable program [Ref. 31]. To effect the long-term evolution of these companies, and improve the quality of his program, the Apache PM must take action now to get all contractors and subcontractors to adopt a philosophy of continuous quality improvement.

The goal is to improve the overall quality of the Apache helicopter and to lower costs of supporting and maintaining the system through the end of its life-cycle by improving the quality of the many subcomponents that make up the helicopter. One of the benefits of creating an all-TQM team is building a stronger, more competitive supplier base that can handle future requirements and programs. [Ref. 38]

B. OBJECTIVE

The primary objective of this thesis is to develop a profile of the total quality management practices of the key contractors and subtier contractors of the Apache Helicopter Program. Useful information can be derived by analyzing the data collected on the profile trends. The Apache Product Manager can use the information to focus his limited resources in those areas that can result in the most improvements in product quality now and in the future.

C. RESEARCH QUESTIONS

1. Primary Research Question

The primary research question answered by this thesis is: What can the Apache Product Manager do to improve the quality improvement efforts and the process capabilities of the prime contractors and subcontractors supporting the Apache Helicopter Program?

2. Subsidiary Research Questions

a. What is the current profile of the quality improvement efforts of the contractors and subcontractors of critical components supporting the Apache Helicopter Program?

b. Why do some companies not adopt a TQM philosophy?

c. What incentives do they require in order to change?

d. What tools are available to the Product Manager to influence the quality improvement practices of the contractors?

e. What benefits can be achieved by adopting a quality improvement philosophy and practice?

D. SCOPE OF THE THESIS

The scope of this thesis focuses on the business operating environment and quality management practices of the prime contractors and critical subcontractors supporting the Apache Helicopter Program. This thesis identifies trends and critical factors that influence or inhibit the quality improvement efforts of companies who produce Apache helicopter parts and provide vital services.

E. METHODOLOGY

1. Step One:

Conduct an extensive literature research to establish the background support for quality management and review current Department of Defense and Army policies on quality management requirements of major weapon systems procurement programs.

2. Step Two:

Develop a questionnaire that will be used in interviews with the prime contractors and subcontractors to solicit specific information on their business operating environment and quality improvement efforts.

3. Step Three:

Gather and analyze the information from the questionnaire.

4. Step Four:

Suggest recommendations for the Apache Product Manager to implement in order to effect changes in the quality efforts of the contractors.

F. ORGANIZATION OF THE STUDY

1. Chapter II

Chapter II provides the background information on Total Quality Management and other methods of quality improvement efforts. This chapter also includes a synopsis of current Department of Defense policies concerning quality management and continuous quality improvement.

2. Chapter III

Chapter III introduces the questionnaire used to collect the data.

3. Chapter IV

Chapter IV presents the results and analysis of the data collected from the questionnaire.

4. Chapter V

Chapter V offers the conclusions and recommendations based on the analysis. The recommendations present options to pursue and actions that can be taken to improve the quality improvement efforts of the supplier-base supporting the Apache Helicopter Program.

II. TOTAL QUALITY MANAGEMENT

A. INTRODUCTION

This chapter provides a basic understanding of the elements of Total Quality Management (TQM). This chapter also presents a synopsis of DOD's policies concerning the quality in the acquisition process and the management of subcontractors.

B. TOTAL QUALITY MANAGEMENT

1. Introduction

Total Quality Management has evolved from the works of quality experts such as Dr. W.E. Deming, Dr. Armand Fiegenbaum, and Philip Crosby [Ref. 28]. The Japanese successfully adopted the quality management style and made significant advances in quality improvements and quality control. The Japanese proved that it was possible to produce a highly technical, high quality product at a low cost [Ref. 22].

In the 1980's, American industries began the slow evolution toward Total Quality Management as the predominant managerial style [Ref. 22]. The level of acceptance has increased dramatically over the years. Quality has become an important element of American products and services. Most customers now select their products based on "best value" criteria instead of lowest price [Ref. 32]. Best value criteria include current process capabilities, past performance in cost, schedule, and quality management, and subcontractor management. The Department of Defense has adopted the policy and practice of buying quality [Ref.28]. Many larger defense companies have adopted TQM to place themselves in a more competitive position for dwindling program acquisition dollars.

The Total Quality Management process can help improve a company's position in the marketplace if the process is developed and nurtured with firm commitment and conviction [Ref. 5]. A thorough understanding of the TQM process is essential to comprehending the difficulties there are in creating an effective, quality-oriented environment. The long-term benefits can only be realized if all elements of the process come together to form a basis of continuous improvement of a product or service, as well as improving the processes to produce a commodity.

2. Benefits of TQM

A company that is persistent and committed to change and continuous quality improvement over the long-term may reap tremendous benefits that can ensure longevity and growth. Some long-term benefits of TQM can include the following:

a. Reduced Costs

By controlling the variations in the processes, costs per unit, fixed and variable, will go down as the process stabilizes to fall consistently within the quality specifications and tolerances of the design. Total Quality Management can reduce costs by:

- Reducing the number of rejects. Rejects cost the customers and the suppliers time and money. The TQM process is refined so that the customer receives the requested product or service on-time and with zero defects. The customer may perform acceptance testing and sampling to ensure the products conforms to the standards of the contract.
- Reducing the amount of waste. Under the TQM philosophy, the product and the processes are designed to optimize the resources used in the production. Resources can include material, components, equipment, people, and time.
- Reducing the need for rework. In his book, *Quality Without Tears*, Philip Crosby espouses the motto, "Do it right the first time." [Ref. 5] The TQM process emphasizes early detection and resolution of problems

and defects. The root causes of problems are determined and long-term solutions are developed to ensure the problem does not recur.

- Reducing the need for massive inspections, testing, and sampling. Inspections, testing and sampling cost time and money. However, as process performance stabilizes over time, there is less need for massive testing and sampling. Companies can certify their quality process capabilities and offer customers consistent reliability and conformance to the standard with less stringent testing and sampling requirements.
- Reducing the need for multi-layered management oversight. To implement a TQM philosophy, a company's organizational structure requires less layers of management. In a TQM environment, employees accept ownership for the process and the results of the quality of the end product. [Ref. 5]

b. Greater Flexibility and Adaptability

The company's ability to meet new demands and adapt to rapidly changing technology will grow with the practice of TQM. The company will continuously improve its processes and capabilities over time to ensure it stays current with emerging technologies and practices. [Ref. 18]

c. Improved Cycle Time

Cycle time is the period of time it takes to go from customer demand to customer satisfaction [Ref. 22]. Practices such as concurrent engineering and cross-functional teamwork can help improve the company's cycle time. In the TQM environment, there is pressure to eliminate non-value-added steps and procedures. This elimination process can save much time and money. [Ref. 33]

d. Increased Productivity

As the quality of the products and processes stabilize over time, productivity will increase. By continuously improving the processes, the company can achieve a higher yield for every production run or service iteration. [Ref. 22]

e. Greater Customer Satisfaction

One of the major goals of TQM is to improve the company's competitiveness. The TQM philosophy focuses the company's energies and resources on meeting customer satisfaction. Customer satisfaction can result in retaining current contracts while gaining many new contracts. If a company's quality is consistent over time, it may be able to develop long-term partnerships with its customers and become the supplier of choice. [Ref. 22]

f. Greater Employee Morale

Employee morale can increase in the TQM environment. Employees develop a renewed sense of ownership and personal responsibility when empowered with the authority and accountability for the success or failure of a given process. [Ref. 21]

Dr. Deming pointed out the benefits of TQM for the workers in his "chain reaction" sequence. In a quality-focused environment:

- Quality improves
- Costs are reduced
- Productivity improves
- Market competitiveness increases
- Business opportunity increases
- Jobs increase. [Ref. 9]

3. The Total Quality Management Environment

Total Quality Management is a long-term, continuous improvement process [Ref. 9]. The success of the TQM process has been proven many times. The Japanese have implemented TQM with much success [Ref. 10]. Many American companies have also realized the benefits of a quality-oriented business operating environment [Ref. 28]. TQM is not a quick-fix

program for a company's quality deficiencies [Ref. 31]. When compared to the traditional management style, TQM is vastly different in leadership style, problem solving techniques, goal setting, interactions with customers and suppliers, and in many other ways as well [Ref. 28]. TQM is a new way of thinking and can change the entire culture of a company. It is this change that scares and confuses many companies into not adopting the TQM approach to management [Ref. 12].

Creating a TQM environment is not an easy process. In many cases it may take five to eight years to fully develop an environment in which quality is as important as cost and schedule. Once the TQM environment has been established it must be continuously improved. It may take imagination and innovation to maintain the required level of enthusiasm and motivation for continuous changing. The process and the people cannot afford to become complacent. Total Quality Management is also referred to as Continuous Process Improvement (CPI). [Ref. 33]

The Total Quality Management process presents a company with many new approaches to achieving its goal and objectives. In converting to a TQM environment a company must completely change its culture to include the management style, employee relations, and problem solving techniques [Ref. 5]. The changes can be as large as organizational restructuring, or as small as modifying the steps or procedures in a manufacturing process [Ref. 7]. The key is that change becomes an integral part of the process. Managing that change within the parameters and capabilities of the company and its employees is the challenge most companies find difficult. TQM requires much devotion, time, and investment of resources to create a productive environment.[Ref. 21]

4. TQM versus Traditional Management

The foremost differences between TQM and the traditional management styles are that the TQM process:

- Focuses on the long-term results instead of the near-term profit margin and output quotas.
- Places quality on par with cost and schedule as important elements of a product.
- Emphasizes designing-in and building-in quality into a product and production process versus inspecting-in quality.
- Emphasizes problem prevention instead of problem detection.
- Focuses on customer satisfaction as a focal point to business success instead of expecting the customer to accept whatever he or/she is given.
- Stresses continuous improvement of all processes and products versus quick-fixes and patchwork solutions to quality.
- Emphasizes teamwork, cross-functional orientation, partnerships, and concurrent engineering versus individual functional and specialized efforts in sequential order.
- Requires employee involvement versus management by edict. [Ref. 28]

5. Elements of the TQM Process

There are many descriptions of exactly what constitutes TQM. Different quality experts define the term in various ways. Basically, TQM is a long-term business operating philosophy that is a compilation of many integrated elements [Ref. 19]. The elements hold true no matter how large the company is, or what product they produce. Successful implementation and integration of these elements provide the company with many benefits such as lower costs, faster cycle times and higher reliability. There are many elements that make up the TQM process.

The major elements of the Total Quality Management Process are:

- Quality capability assessment,
- Visionary leadership,
- Company-wide commitment to continuous improvement,
- Organizational structure and staff relations,
- Teamwork,
- Employee involvement,
- Customer relations,
- Supplier relations,
- Goals and objectives,
- Strategic and operational plans,
- Continuous training and education, and
- Continuous measurement of processes. [Ref. 22]

a. Quality Capability Assessment

To begin the change to a continuous quality improvement environment, companies must establish where they are in terms of quality and customer satisfaction. Are they building a product that the customers want? Do they have the capability of correcting and preventing defects? Do they have the capability to adapt to the rapidly changing technology? They must realize their quality capabilities so they know where to begin to improve. They can conduct a self-assessment using the standards and criteria of the Malcolm Baldrige National Quality Award established by the U.S. Department of Commerce [Ref. 13], or they can measure their capabilities against the industry leaders. Feedback from external sources such the customers and suppliers, and internal sources, such as the employees, can provide much of the information needed

to gauge the company's capabilities [Ref. 17]. Once they have established a starting point, the companies can begin to assess where they want to be and by when.

b. Visionary Leadership

The TQM process requires top-down implementation. One of Dr. Deming's key points to quality control is the institution of leadership [Ref. 1]. The company's senior leadership must be completely supportive of the quality goals and objectives of the company. It is their responsibility to remove any barriers to quality improvement. Another point from Dr. Deming's philosophy is to drive out the fear of change [Ref. 11]. Senior leaders can directly affect the level of tension and fear caused by changes to a company's operating culture. Senior leaders establish the environment and groundwork for the company's quality improvement process. It is their leadership and vision that the managers, supervisors, and workers at all levels use as an example for their roles in the quality improvement process [Ref. 20]. It is their vision that will set the future course of the company in philosophy, decision making, goal setting, and general day-to-day operations. The company must know what its purpose is, where it is going, and how it is going to get there, in broad terms. The senior leaders must be vocal advocates of quality [Ref. 5]. They must take every opportunity they receive to personally convey the company's desire to continuously improve. Charisma, personal knowledge, communication skills are all important to the leader in the TQM environment. The senior manager must:

- Understand, practice, and teach TQM principles and practices before expecting the same from his or her subordinates.
- Be completely committed to long-term quality improvement.
- Serve as a role model for quality improvement.

- Establish the broad strategies, goals, and objectives that focus the energies and resources of the company toward continuous process improvement.
- Encourage innovative thinking, which sometimes may be the only way to overcome a problem or improve the process.
- Be a vocal advocate of quality and take every opportunity to personally convey the message of the quality-first philosophy. [Ref. 12]

c. Company-wide Commitment

Everyone in the company must be committed to continuous improvement [Ref. 22]. Workers at all levels have specific responsibilities that may impact the company's product. Dr. Deming refers to it as creating a constancy of purpose [Ref. 1]. The company must adopt a new philosophy that focuses on quality and customer satisfaction [Ref. 1]. Establishing the commitment takes time and energy. To build commitment, the company must break down the barriers to change and convince the managers and workers, who are often skeptical of a "new program", that TQM is an operating philosophy and not just a quick-fix program. The company and all the smaller subunits must have a single focal point and driving force that the workers can follow in their day-to-day operations. [Ref. 5]

d. Organizational Structure and Staff Relations

The TQM organizational structure varies from company to company. Some companies invert their hierarchical organizational structure to reinforce the idea that the top management and staff are a service support organization for the front line units. Many companies prefer the egg within an egg, or the cluster organization. Some companies have developed non-bureaucratic organizations that rely on the interaction and cooperation between different individuals and subunits to conduct business. [Ref. 25]

TQM structures require less management oversight because much of the responsibility for the day-to-day operations is passed down to the process teams and workers [Ref. 19]. In addition, TQM relies on vertical integration of functions rather than the traditional horizontal 'stovepipe' structures. Kaiser Electronics of San Jose, California offers an example of the vertical integration. Kaiser has identified seven key business processes; 1)Business Development; 2)Engineering; 3)Production; 4)Procurement; 5)Program Management; 6)Employee Development; and 7)Preferred Supplier Certification . Kaiser has seventeen functional departments ranging from strategic planning to finance and marketing. Each of these key processes has formed a process team made up of all functional departments that have any involvement in the process. One department is assigned as the process-owner and leader. All other participating departments are subordinate to the process leader when the issue involves a process. [Ref. 33]

e. Teamwork

Teamwork is a very important element of the TQM process [Ref. 4]. Compartmentalized activities are replaced by a cooperative team effort [Ref. 9]. The need for cooperation is essential because TQM is a process-oriented system [Ref. 4]. For a single product, there are many steps or processes that go into getting it from customer demand to customer satisfaction. There are many individuals and functional departments contributing to the different processes. Every individual or department contributing to a process is a member of the team and has input to changes and quality improvements for the process. The team must have a focal point to direct its efforts in an effective, efficient manner. The team goals become the individual's or department's goal. [Ref. 4]

Successful teamwork requires open communications and sharing of information [Ref. 4]. Members of the process teams offer a myriad of experiences, technical knowledge, and perspectives on the process. The diversity of ideas and outlooks can greatly enhance opportunity for process improvement. As the team identifies problems and opportunities for change, each team member has a chance to voice his or her concerns and provide input to the process. In the end, all the team members will have a full understanding of the changes and must agree to support the efforts. [Ref. 33]

f. Employee Involvement

The TQM process emphasizes the complete involvement of employees at all levels in making quality decisions. The process creates a feeling of ownership [Ref. 22]. The workers have the greatest impact on the process. They are the ones who must put the operational plans into action; they turn the switches, solder the joints, handle the forms, and so on. It is at this grassroots level that quality can be most affected. The workers must be given the proper tools for the job [Ref. 12]. The tools are knowledge and authority. Knowledge is obtained by training and experience, and the authority is delegated. The employees are empowered to make decisions, voice suggestions, and take an active role in the quality improvement process [Ref. 33]. This is contrary to traditional authoritative management practices of the past [Ref. 12]. The supervisors and managers must learn to be mentors and coaches instead of autocrats. The empowerment of the workers can raise morale and productivity once the employees begin to feel they have a direct impact on the process's success or failure.

Kaiser Electronics offers a good example of the dynamics of employee empowerment. Kaiser's continuous process improvement efforts have given the workers, from highly trained technicians to office clerical workers, direct input

into the process controls and implementation. Employees at all levels are given the opportunity to participate on Process Action Teams (PATs). The PATs establish procedures, policies, and resolve problems for each of the processes. As a result of the efforts of the employees, the quality of their processes has increased dramatically over a short two-year period. [Ref. 33]

A program of recognition and rewards can help build morale and maintain the level of enthusiasm as the process of improvement builds. [Ref. 18]

g. Customer Relationship

TQM is focused on customer satisfaction as a premise of success [Ref. 10]. There are internal and external customers. The different organizations and departments within a company have customers and suppliers from other organizations within the company. Any supplier or customer that is outside the company is an external customer. The company as a whole must focus on the external customer [Ref. 33]; however, the different organizations within the company must treat their internal customers with the same degree of customer service as they do external customers. They must identify clearly what the customers want as a product, produce it to their satisfaction [Ref. 17], get their feedback on the product, and institute the changes necessary to improve the product and process. For an external customer this is especially important. The suppliers must be responsive to the customer's needs [Ref. 5]. Whenever possible, the suppliers should establish long-term partnerships with the customer [Ref. 1]. They should become a member of the customer's quality team. Open communications and feedback from the external customers are very important [Ref. 39].

h. Supplier Relationship

Similar to the customer relationship, the company should establish a close relationship with its suppliers and vendors. It should encourage the suppliers to actively participate in the quality improvement process [Ref. 22]. There are many companies that follow Dr. Deming's recommendation to reduce the number of suppliers [Ref. 1]. The company should rid itself of suppliers that do not contribute to the quality improvement efforts of the company and invest in quality suppliers [Ref. 1]. Establishing partnerships and long-term relations is important to opening communications and understanding each other's needs and capability. The company should provide feedback to the suppliers to let them know how they are meeting its needs. [Ref. 41]

Many companies today are certifying their suppliers' quality improvement efforts and process capabilities. The certification process allows the suppliers an opportunity to gain the customer's confidence enough that costly acceptance inspections can be eliminated and the supplier can receive preferential consideration for future contracts and some bigger profit margins from the cost savings as a result of the quality improvement efforts. McDonnell Douglas Aerospace certifies its preferred suppliers on a three-tier level [Ref. 33]. To obtain the highest certification rating, suppliers must consistently provide on-time delivery, high quality products with no defects, and provide rapid resolution of problems and issues. In addition, the suppliers must demonstrate the ability to continuously improve the quality. [Ref. 39]

i. Goals and Objectives

The company must establish long-term goals and objectives to focus the improvement efforts [Ref. 33]. As an example, Motorola's primary goal for the past five years has

been to achieve a six-sigma process capability for the entire company. Texas Instruments has a very similar process goal that is explained in a later paragraph.[Ref. 42] This goal has been the driving force for the company's quality improvement efforts. It has successfully combined a seemingly impossible goal with an aggressive philosophy and innovative approaches to achieve substantial results in a very short period of time. [Ref. 23]

Annually, the company should evaluate its performance against the goals and objectives it established [Ref. 13]. The goals and objectives are set according to the desired rate of change. The companies must be sure to use good business practices when setting the rate of improvement. An aggressive rate of change can be very costly and risky. A slower, more deliberate rate of change is easier to manage. [Ref. 33]

j. Strategic and Operational Plan

The company must establish a broad scope strategic plan to accomplish its goals and objectives. Then it must institute an executable operations plan that allocates resources and sets schedules to achieve the goals and objectives. The plan may require innovation and flexibility [Ref. 33].

The Malcolm Baldrige Award criteria consider strategic planning as an essential element in the company's quality improvement process. To be considered for the Baldrige award, a company must show a strategic business plan that focuses on the customer and operation performance requirements. Specifically, the award criteria address a plan that focuses on customer satisfaction, customer retention, and market shares. The Baldrige award also considers the operational plan as it contributes to the short-term and longer-term productivity growth and cost competitiveness. The

company must 1) understand the key customer's requirements, 2) optimize resources, and 3) ensure the plan is executable. [Ref. 13]

k. Continuous Training and Education

The Japanese believe that quality starts with training and ends with training [Ref. 30]. It is a way of reinforcing the message that quality is important [Ref. 18]. The company must provide the managers and employees with the right tools to do their job. Knowledge and experience are very important tools. Well-trained employees have a better opportunity to contribute positively to the quality improvement efforts [Ref. 21].

The training and education process must begin by deciding what job skills are required to make quality improvements [Ref. 22]. The company may choose to hire consultants to conduct the training, or it may choose to establish its own training program. The goal is to give every employee the job skills, technical knowledge, and job experience he or she needs to do the job right the first time [Ref. 5].

Training and education must be continuous [Ref. 22]. The company must invest in its employees in order to improve the long-term quality improvement efforts [Ref. 13].

1. Continuous Measurement

TQM requires a great deal of measurement. A key to success in continuous improvement is to reduce variations in the processes [Ref. 23]. The company must continuously monitor its processes to ensure they operate within normal allowable parameters [Ref. 8]. When a process is found to be out of tolerance, the company must seek the root cause of the problem and correct it [Ref. 3].

Statistical Process Control (SPC) has become the primary means of managing the measurement process. There are seven basic SPC tools: flow charts, cause and effect charts, checklists, histograms, pareto charts, scattergrams, and control charts. [Ref. 22]

The control chart is a very popular tool in manufacturing [Ref. 22]. In every process there will always be variation [Ref. 8]. The key is to control and reduce that variation. The process team must select acceptable upper and lower control limits and a target value for the process. The process is then measured. When the process is found to exceed the limits, the process team must try to find the root cause for the deviation. Once the root cause is agreed upon, the process team can take corrective actions to ensure the problem does not recur [Ref. 22]. As the process variations become stable about the target mean, the process team may choose to tighten the standards. By allowing the process to fall within a set of boundaries, the process team can allocate their limited resources on the outlier and serious deviations. [Ref. 8]

The process team must first decide what to measure and how the data collected will be used to make changes to the process. It is important to ensure that the data collection has a purpose. Accumulating data for collection's sake is wasteful [Ref. 33]. The process team may choose to follow the works of Genichi Taguchi, a quality control expert, who contributed the means to establish adequate tolerance designs and limits on specific values through the statistical design of experiments. [Ref. 9]

6. Texas Instruments's Six-Sigma Producibility

Texas Instruments (TI) is a world-class manufacturer of electronic products. TI's products are extremely complex and involve hundreds of parts and thousands of steps in the processes to design, build, and deliver to the customer's satisfaction.

Modeled after Motorola's quality improvement process, Texas Instruments developed a quality goal of achieving six-sigma producibility capability, or less than 3.4 defects per million opportunities (dpmo) for those defects to occur (99.99966 percent success rate), for all products and processes. Texas Instruments' six-sigma capability is an excellent example to illustrate the application of the elements of the TQM philosophy. DOD's major weapon systems program can use Texas Instruments's path to successful quality control as a model to improve the overall quality of the weapon systems.

Most competent companies operate at a four-sigma level. A four-sigma level of producibility will result in a 99.379 percent success rate. In most circumstances that is considered a very respectable accomplishment. However, counting the total number of opportunities for a defect to occur (the reliability of every part and every step in the process), there would be well over 6000 defects for every million opportunities. There can easily be millions of opportunities for defects to occur when designing, producing and delivering a complex product using complicated processes, repeated many times over. Those 6000 defects can cause the loss of time, money, and resources to correct.

To reach its goal, Texas Instruments has had to reduce the number of defects per unit by a factor of six each year. The reduction was accomplished by effective application of the elements of TQM. Texas Instruments has reduced the number of opportunities for defects by:

- Reducing the number of components or parts in a product.
- Increasing the reliability of the parts and components (decreasing the probability of failure).
- Reducing the number of steps in a process. Eliminating the non-value added steps.
- Simplifying the steps in a process and the parts of a product.
- Controlling the variation in the processes that cause defects (automation of the process and better training for the workers).
- Designing quality into the products and processes. Texas Instruments makes extensive use of simulation and modeling to identify and correct problems up front and early.
- Working with its suppliers and vendors to improve the quality and reliability of the products and services they subcontract. Texas Instruments's suppliers must be quality-focused to achieve a six-sigma capability.

In addition, Texas Instruments has successfully reduced its cycle time by twenty-five percent each year. Where it used to take months to design, build and deliver a new product, it now only takes weeks. Reducing cycle time has allowed Texas Instruments to become more responsive to its customer's needs and keep up with rapidly changing technology.

Texas Instruments has improved its ability to compete in the global market by methodically and deliberately controlling the quality environment. It now has a quality-focused culture that will enable it to continuously improve its processes and products forever. It has removed barriers to change and encouraged innovative thinking to solve problems. To reach its goal, TI had to accept risks. [Ref. 16]

7. Barriers to Achieving TQM

Many companies have attempted to adopt a TQM business operating philosophy but have fallen short or failed completely. There are other companies that have not even attempted to change. Some of the reasons for failure may include the following:

- Fear of change. Company management is not willing to accept the risks involved in reorganizing and adjusting to their new roles.
- Lack of technical knowledge and understanding of TQM process.
- Lack of company-wide commitment. TQM is treated as a slogan and a meaningless concept.
- Lack of visionary leadership and focus. Managers talk about long-term quality but their focus remains on short-term profits.
- No immediate threat to survival of the company. Customer are not demanding for quality improvement and there is no competition.
- Lack of available resources: time, money, people, and equipment.
- Concentration on the short-term payoffs instead of the long-term benefit.
- Inability to communicate quality requirements and demands with customers and suppliers. [Ref. 33]
- Inflexibility of the company to accept new ideas and adapt to the changing environment.

C. DOD'S EMPHASIS ON QUALITY IN THE ACQUISITION PROCESS

DOD has placed an increased emphasis on improving quality in the acquisition process. A contractor's past performance and quality capabilities play a very important role during the

source selection process for major weapons systems procurement [Ref. 35]. The contractor's suppliers and vendors are important elements in the contractor's quality capabilities.

1. DOD's Quality Policy

The Defense Systems Management College summarized DOD's policy on quality from the *Department of Defense Posture on Quality*, March 1988. The DOD policy is:

- Quality is absolutely vital to our defense, and requires a commitment to continuous improvement by all DOD personnel.
- A quality and productivity-oriented defense industry, with its underlying industrial base, is the key to our ability to maintain a superior level of readiness.
- Sustained emphasis and concern, with respect to high quality and productivity, must be an integral part of DOD daily activities.
- Quality improvement is a key to productivity improvement and must be pursued with the necessary resources to produce tangible benefits.
- Technology, one of our greatest assets, must be used widely to improve continuously the quality of the defense systems, equipment and services.
- Emphasis must change from relying on inspection, to designing and building quality into the process and product.
- Quality must be a key element of competition.
- Acquisition strategies must include requirements for continuous improvement of quality and reduced ownership costs.
- Managers and personnel at all levels must take responsibility for the quality of their efforts.
- Competent, dedicated employees make the greatest contributions to quality and productivity. They must be recognized and rewarded accordingly.

- Quality concepts must be ingrained throughout every organization with the proper training at each level, starting with top management.
- Principles of quality improvement must involve all personnel and products, including the generation of products in paper and data form. [Ref. 34]

2. Acquisition Reform and Streamlining Measures

Under section 800 of the National Defense Authorization Act for Fiscal Year 1991, Congress ordered the officials responsible for administering DOD acquisition laws and regulations to appoint an advisory panel of Government and private-sector experts to review all laws affecting the DOD procurement processes. The advisory panel was to specifically address the laws and regulations with the view towards streamlining the processes. As a result of the 1991 Section 800 Panel Report, DOD has developed a new approach to reform and simplify the acquisition process. The three guiding principles are:

- Reduce acquisition costs through the adoption of business processes characteristic of world-class customers.
- Ensure that the United States maintains a strong, globally competitive national industrial base that can support DOD's needs.
- Take full advantage of rapid technological advances by streamlining procedures so that DOD easily can purchase state-of-the-art commercial products and other technology. [Ref. 28]

To improve the acquisition process DOD has instituted some of the following changes:

- Encourage the use of best commercial practices for major weapon systems procurement programs.
- Limit the use of military specifications; allow commercial standards to be used.

- Change and eliminate unnecessary policies and regulations that restrict and inhibit the acquisition process.
- Develop a long-term relationship with industry built on trust. [Ref. 34]

3. Subcontractor Management and Quality Improvement

In many major weapon systems procurement programs, over 60 percent of a prime contract value goes to subcontractors. Subcontractors play a significant role in the quality of a product. As the technical efforts of subcontractors continue to increase, DOD is directing more attention to the quality control efforts of the subcontractors. This is, however, encroaching on the traditional privity of contract between prime contractors and subcontractors. [Ref. 27]

"Privity of Contract" is defined as the direct legal relationship between two parties of the same contract. The Government's relationship with subtier contractors is indirect. The prime contractors are responsible for determining the responsibility and reliability of their prospective subcontractors. Any problems or concerns with the subcontractors must be handled through the prime contractor. [Ref. 27]

The Government is responsible to insure the prime contractors have an adequate quality assurance process for their subcontractors. In limited cases, the Government may choose to perform quality assurance inspection of critical components from subcontractors. This inspection does not relieve the prime contractor of its responsibility for quality assurance. The Government should periodically have the prime contractors conduct a vendor quality survey of their subcontractors to ensure steps are being taken to improve the quality of the products. [Ref. 27]

4. DOD's Downsizing Affects on Defense Industry

As DOD downsizes its infrastructure and personnel base, the need for major weapon systems procurement also decreases. DOD does not need as many tanks, ships, and aircraft as it once did. This decrease in defense spending on acquisition has caused the defense industry to move toward restructuring and downsizing [Ref. 36]. DOD has taken the approach that it will allow the market forces to restructure the defense industry [Ref. 36]. The market forces are pushing many companies to get serious about their quality capability. This includes reducing the size of their subcontractor and lower-tier supply base while requiring higher quality and on-time delivery from the remaining suppliers. [Ref. 35]

This reduction may cause the elimination of some key producers of critical parts and services, requiring the dependency on foreign sources. Although the hands-off approach to restructuring allows only the best companies to remain, there is a risk that some key sources of critical materials and services may be lost. DOD must take steps to assist the defense industry to retain certain critical services and producers. [Ref. 35]

D. CHAPTER SUMMARY

The Total Quality Management philosophy has been successfully implemented by many world-class leaders in the commercial and defense industries. TQM can be used by any size company in almost every industry. The TQM process is tailored for each company; however, there are key elements that must be addressed in order to achieve the benefits of the process. The elements are: capability assessment, leadership, commitment, organizational structure, teamwork, employee involvement, customer and supplier relationships, strategic and operational plans, goals and objectives, training, and metrics. The benefits of implementing a TQM philosophy are: cost

reductions, increased flexibility and capability, increased productivity, improved cycle time, greater customer satisfaction, and increased employee morale. Some of the barriers to successful implementation include: fear of change, lack of knowledge and understanding of the TQM philosophy, lack of resources, lack of leadership, lack of commitment, and lack of available resources.

In recent years, DOD has taken many steps to improve the quality of its major weapon systems and to streamline the acquisition process. DOD has eliminated many of the barriers and restrictions that inhibited many defense contractors' quality improvement efforts. One of the key changes was to return the responsibility for quality back to the contractors.

The prime contractor has the responsibility to maintain an active quality assurance process and to ensure that its suppliers and vendors do the same for all materials and components. As a result, many defense contractors are downsizing the supplier-base, and retaining only quality suppliers and vendors.

III. THE QUESTIONNAIRE

A. INTRODUCTION

This chapter presents the questionnaire used to gather the data for the analysis. The *Questionnaire Construction Manual* was used as a reference during the development of the questionnaire [Ref. 37]. The questionnaire was broken down into four areas of interest; 1) background information about the contractor, 2) profile of the product or service supporting the Apache Helicopter Program, 3) profile of the quality practices of the contractor, 4) profile of the non-TQM contractors, and 5) questions about the communication process and solicitation for ideas.

B. SECTION ONE

This section is intended to develop a profile of the company and the company's products or services that contribute to the Apache Helicopter Program. The questions are:

1. Participant's name and position?
2. Telephone/ Fax number?
3. Company?
4. Prime or subtier contractor?
5. Who is the prime customer?

Questions one through three collect basic information about the company and the person answering the questionnaire. It was important to determine the person's position in the company in order to ascertain his association with the product and the quality control measures for that product. Questions four and five were posed to determine the contractual distance between the company and the Apache Helicopter Program. The lower the tier, the fewer influences the Product Manager has on the contractor's quality control efforts.

C. SECTION TWO

Section Two profiles the product or service provided. The questions are:

1. Products or services contributing to the Apache Helicopter Program?
2. Complexity of product or service?
 - General service
 - Simple assembled
 - Specialized service
 - Complex assembled
 - Raw Material
 - Complex w/integrated circuits and software
 - Simple component-no moving parts
3. How is your product produced?
 - Custom built
 - Mass production
 - Assembly line Production
 - Cross-functional team-built
4. How many do you produce monthly for the Apache Helicopter Program?
5. How is your product inspected for quality and conformance to the specifications?
6. Is the product or service used in any other Government program or commercial application?

These questions develop the background information that is important when determining the complexity of the product and the processes involved in producing and inspecting the product. More complex products and processes need an operating environment that fosters tight control of the many procedures and resources involved to ensure the efficient integration into the product. Question six of this section was developed

to determine how their products affect other Government programs. If they do affect more than one program, then it is important to coordinate the quality demands as a single customer, creating a greater pressure to continuously improve the quality processes.

D. SECTION THREE

Section Three profiles the Total Quality Management practice of the company. The questions are:

1. Has your company adopted the practice of Total Quality Management or similar operating environment?
2. What were the reasons for changing?
 - Customer demanded
 - Competition - stay with or get ahead
 - The other way not working
 - Good business sense
3. How long has your company practiced TQM?
4. Do you have a dedicated quality improvement staff?
5. Do you practice statistical process control (SPC)?
6. How much TQM training is conducted and how often?
7. Are you certifying your supplier base and encouraging them to adopt a management style that fosters continuous quality improvement?

These questions were developed to ascertain the quality management experience of the company. Questions one through five deal directly with cultural and structural facets of the company's organization. Training is a very important tool for reinforcing the quality improvement efforts; the company must be continuously provided the means to improve the technical knowledge and job skills of the workers at all levels.

Question seven was designed to establish the company's efforts to develop its suppliers' quality control processes, especially for critical subcomponents and services. A company dedicated to quality improvement will allocate the necessary resources to assist its suppliers' quality control capabilities. This may include providing technical assistance and capital investments.

E. SECTION FOUR

Section Four profiles the non-TQM contractors.

1. How would you describe your business management environment?
 - Management by Objectives
 - Management by Exception
2. Do you intend to adopt a TQM environment?
3. Reasons for not adopting TQM?
4. Have you received TQM training?
5. Does your main customer encourage the adoption of TQM?
6. If offered, would you participate in a TQM training session or allow a team of experts to review your present procedures and make recommendations on how to change?

In section four, the questions were created to develop some background information on those contractors who have not adopted a quality-oriented approach to management. By accumulating reasons for not adopting a continuous improvement business culture, this study may be able to determine some ideas to overcome the resistance to change. The fourth and fifth questions attempt to assess whether or not the company and its leaders understand the TQM processes, and if it is receiving encouragement to change from its customers.

F. SECTION FIVE

Section Five profiles the communication process and solicits ideas for improving.

1. Are you aware of the Apache Helicopter PM's goals for continuous quality improvement?
2. How does your prime customer relay the quality goals of the Apache Product Manager?
3. How do you receive the feedback on the customers' satisfaction?
4. How can the Apache Helicopter PM provide encouragement, incentives, and assistance for improving the quality of your product?
 - More training
 - Provide cash and contract award incentives
 - Have a team of experts review procedures and recommend changes
 - Share the initial investment expenses
 - Provide Government Furnished Equipment (GFE)

Open communication between customers and suppliers is an essential part of the quality improvement process. As a prime customer, the PM must be vocal in his demands for continuous quality improvement in the products he purchases. Question five tries to discover whether or not the Apache Helicopter Product Manager's long-term vision for continuous process improvement has been disseminated to the lower levels of contractors.

G. CHAPTER SUMMARY

The questionnaire was developed to create a basic profile of a few of the contractors and subcontractors supporting the Apache Helicopter Program. The questionnaire was developed to serve as a platform for open and frank discussion of quality

management at the subtier levels of contractors. The four sections addressed are: organizational background, product background, TQM experience, and communication process. An analysis of the responses to the question is presented in Chapter IV.

IV. ANALYSIS OF THE RESPONSES TO THE QUESTIONNAIRE

A. INTRODUCTION

This chapter provides an analysis of the responses to the questionnaire presented in Chapter III. The questionnaire was conducted telephonically. Each interview lasted between ten and fifteen minutes. The respondents were very willing to contribute to the study and shared their experiences and personal knowledge of TQM and continuous process improvement in an open and frank manner.

B. SECTION ONE - ORGANIZATIONAL INFORMATION

The responses to the questions in section one provided a profile of the respondents and the companies they represented. Two prime contractors, McDonnell Douglas Helicopters Systems (MDHS) and Martin Marietta Technologies Electronic and Missiles Division, were interviewed. Ten subcontractors to Martin Marietta participated as did eight subcontractors to MDHS. The companies represented a myriad of specialized industries from aluminum casting to optical coating. The companies also represented various size companies from large, multi-faceted companies with thousands of employees, like Martin Marietta, to small businesses with less than sixty personnel, like the New Hampshire Ball Bearing Company. All the individuals who answered the questions were quality control managers or product managers who were very familiar with the products and services provided by the company and each had many years of experience in the field of quality management.

From the responses to the questions in section one it is determined that the companies interviewed represented an adequate cross-section of industries and company sizes of the total population of contractors and subcontractors supporting the Apache Helicopter Program. Further, the individuals who

participated in the interview were experienced enough in the field of quality control to provide credible input to the study.

C. SECTION TWO - PRODUCT INFORMATION

1. Responses to the Questions

From the interviews it can be concluded that the contractors and subcontractors supporting the Apache Helicopter Program represent the leaders in their industry. In all cases, their products are used in more than one Government program. Several of the companies interviewed support different Government programs through various prime contractors.

Some of the more diverse companies questioned have split their Government-sponsored programs into separate divisions. The parent companies of these separate divisions produce goods and services for the commercial market, while the entities interviewed produce goods and services solely for the Government programs. Other less diverse companies produce goods and services that are used both in the commercial market and Government programs.

All of the companies interviewed produce and assemble highly technical products and services. The products require highly trained personnel and extremely complicated machinery and state-of-the-art processes.

The production processes varied by industries. Most companies, however, produced components in small batch quantities. The more complicated and specialized products were custom built. Many companies use a series of small assembly lines and cross-functional teams to assemble various components and to convert raw materials into usable components.

McDonnell Douglas Helicopter Systems is producing only a small number of Apache helicopters per month. Most components and spare parts are purchased in limited quantities. The Apache helicopter and spare parts production are in decline as the final lot of helicopters is completed. To keep the production line open, the Army is developing the Longbow Apache; however, it has not been approved for full-rate production yet. There is also the possibility of increasing foreign military sales of the Apache in order to maintain the demand for parts and services. Every company interviewed stated that the production rate of components for the Apache helicopter was low.

All companies interviewed used some automation and computers to enhance the production process. For example, one subcontractor produces custom-made switches for the Apache. It only produces 20 or less a year in a single batch. Each switch is individually constructed by a highly trained and experienced technician. The company only uses its computers to measure and track product quality.

For the first two levels of contractors, continuous quality inspections are very important. The products are thoroughly inspected for quality throughout the production process. Most of the components have such precise tolerances and quality standards that inspections and testing are mandatory for flight safety. At the third level of contractors, the testing and inspection processes were less stringent. More than half of the components produced at the third-tier level received the quality inspection at the second-tier contractor prior to use.

2. Analysis

The Apache helicopter is a very multifarious system. The Apache Product Manager must demand tight quality control over every product and process that make up the Apache program. The

contractors and subcontractors supporting the Apache program need a management philosophy like TQM. Their products and processes are so diverse and technically complex that only a quality-focused organizational structure and business operating culture could meet the current and future demands for quality improvement. The processes have to be controlled to reduce the variations that cause waste, rejects, and rework. The contractors at all levels must develop an operating system that will allow them to quickly adjust to changing technology and adopt best commercial practices. This step towards a quality-oriented business operating philosophy will promote a stronger contractor-base and help reduce cycle time and costs for the program.

Through the acquisition reform process, the Department of Defense must coordinate the quality demands of all its various programs that use similar components and services. This level of demand can be used to apply pressure on the contractors and subtier contractors to improve their quality control efforts. DOD quality improvement demands will have the most influence on companies whose primary source of income is from Government programs. The Apache Product Manager must be able to join forces with other programs in DOD to reach the lower-tier subcontractors with quality improvement demands. This will, however, require DOD leadership to cross the barriers that separate the various programs and the various military services.

The lack of resources is a massive barrier to quality improvement. The low-rate production level of the Apache Helicopter Program may create a resource problem. For many of the components and services, the orders are not in large enough quantities, or are not placed often enough to make use of economies of scale to reduce costs or provide a return on the investment for upgrading the elements of the processes.

The use of automation and computers will help control variation in the processes. As variations become stable, costs are reduced and cycle-time decreases over the long-term. The technology and equipment required for using computers and automation in the process requires a great deal of up-front investment.

Companies are becoming increasingly specialized in highly technical fields of manufacturing and service providing. This specialization allows companies to concentrate their limited resources on improving their products and processes. On the other hand, specialization requires a great deal of interdependency. The companies must coordinate their efforts and maintain a common focus on time and cost reduction while improving the quality of the product and processes. As specialization increases, so will the need for a quality management philosophy like TQM. The Apache Helicopter Program will benefit in the long-run as companies form long-term partnerships and work as a unified team towards a common goal.

D. SECTION THREE - TQM

1. Responses to the Questions

Total Quality Management is the management philosophy of choice. Every company interviewed in this study has adopted TQM as its primary business operating philosophy. According to the second-tier subcontractors interviewed, less than 50 percent of the third-tier suppliers formally practice TQM or CPI.

The prime contractors embraced TQM between five to ten years ago in order to improve their competitiveness in the defense industry. Only three of the second-tier subcontractors adopted a TQM approach to management of their own volition. The remaining subtier contractors converted because their customers, the prime contractors, demanded the change.

Every company interviewed had a staff dedicated to quality assurance and quality improvement. The staff's main function was to oversee the quality improvement processes and to provide quality training for the company.

2. Analysis

The larger defense contractors have developed well-defined quality processes. They have demonstrated their capability to manage large, complex programs with special emphasis on cost, schedule, and quality. Both McDonnell Douglas and Martin Marietta have institutionalized the TQM process. Quality improvement has become a very important part of production process. Their TQM processes and organizational restructuring have taken many years to develop. They have made a significant investment of resources to improve their supplier-base to include training assistance, quality process certifications, and supplier-base reductions. Both Martin Marietta and McDonnell Douglas will continue to improve their capabilities and processes for the long-term.

The second-tier subcontractors have adopted TQM primarily as a result of the pressures and incentives from the prime contractors. Many of the companies interviewed have concentrated their efforts on quality control for ten or more years, but they have only recently formalized the process to achieve continuous improvement. Their improvement process is well established and focused on long-term refinement of the quality control of their products. To overcome the barriers to change, the smaller companies have had to accept a great deal of risk. The risks taken by the companies should pay off in the long-run by improving their quality capabilities and making them more competitive for future contracts.

The companies that have accepted TQM as their management philosophy have created a working environment that can adapt to the changing market demands, including the new demands from

DOD as a result of the acquisition reform process. Contractors will be able to provide products that meet and exceed the military's demands using the specification requirements of form, fit and function rather than the rigid system of military specifications. They have successfully integrated the elements of TQM to include committed leadership, supplier and customer relationship development, and quality metrics using statistical process control. As a result, they have become more responsive to the demands of the DOD programs like the Apache Helicopter. Most of the companies have made the investment in their employees in job training. They have seized the opportunity to improve the long-term job skills of their workforce by conducting in-house quality training on a regular basis. The companies must continue to use training as a tool to reinforce the quality improvement goals of the company and the programs they support to include continuous process improvement and reductions in defect opportunities. They must emphasize long-term base knowledge as well as specific job skills.

The Apache Product Manager can take advantage of the lessons learned from the successes and failures of the companies currently using the TQM approach to management. The Apache PM can use the successful companies as positive models while emphasizing the need for continuous improvement. The failures and setbacks can be used to emphasize the risks involved and to develop methods of avoiding the pitfalls.

The contractors and subtier contractors using TQM represent a significant portion of the program. Through their efforts and the examples they set, the Apache Helicopter Program will continue to improve over the long-term.

E. SECTION FOUR - NON-TQM

1. Responses to the Questions

Every company interviewed for this study practiced TQM and CPI. The questions in section four were not directly addressed. However, all of the quality managers from the second-tier contractors offered some information about their non-TQM subcontractors and suppliers.

Less than 50 percent of the third-tier subcontractors practice a formalized process of TQM. A majority of the third-tier subcontractors are small, specialized businesses with limited resources such as people, equipment and money. The second-tier contractors conduct the inspections and testing of the components and materials coming from these contractors.

2. Analysis

Providing a quality product is still very important to the small businesses. They considered themselves mastercraftsmen and take pride in meeting and exceeding the terms of their contract. One of the major quandaries is that they do not have the drive and the established procedures to seek continuous improvement. They manage each job order separately. The contracts specifically supporting the Apache Helicopter Program represent a very small percentage of their business. The orders are placed infrequently and in small quantities. Many of the companies have become so specialized that they have very limited markets. They deal primarily in such small contracts that it becomes imperative for them to obtain many small contracts in order to remain profitable in the long-term.

According to Philip Crosby, quality improvement can be cost-free. A company can make small procedural or organizational changes that can greatly improve the efficiency and quality of a product [Ref. 12]. However, these small changes can only improve the process so far. To make the big

changes, it takes time, money, equipment, training, and people. Many of the smaller, specialized companies lack these resources.

Many small companies do not have the human resources to dedicate to quality improvement. Some of the smallest companies, in order to dedicate a person to quality improvement, would have to hire someone, which would increase their labor costs, or place the responsibility on one of their few workers.

Many small companies do not have the capital needed to invest in state-of-the-art equipment for manufacturing and testing. Some companies cannot even afford to calibrate their equipment as often as they should. They rely on the experience and technical training of the machine operators to ensure the quality of the product. Buying new equipment and reorganizing the company cost time and money.

Many smaller companies are short-term oriented. They live from contract to contract. They may have long-term goals, but the uncertainty of future contracts cripples their ability to plan and prepare. It is easier to concentrate on the short-term.

The lack of training and understanding of the TQM process is another major reason for the small companies' lack of interest in the TQM process. To the average small business owner, TQM is a vague concept with no substance. What works for the larger company does not necessarily translate to meet the needs of the small business. For the smaller companies the TQM process must be approached in a different manner. The needs and capability of the small company are vastly different from the bigger companies that have more resources to call on. TQM training is still done by consultants and specialized schools. Many smaller companies believe they do not have the time to devote to TQM training.

Some companies do not feel the need to change because they do not feel their business is threatened. Highly specialized companies do not have any competition. Their product is so unique and hard to duplicate that no one can offer the same product without much time and money. When a company is a sole domestic source for a product or service, it has the advantage over the customers. The risk of not adopting the business operating environment for continuous improvement must outweigh the risk associated with changing. The customer always has the opportunity to refuse the product; however, the costs of developing its own internal capability to produce the product or service, or finding a new domestic source for the product or service must outweigh the costs incurred because of poor quality control (rework, rejects, waste, and additional inspection and testing requirements).

The smaller companies need more incentives like the promise of higher profits or special consideration for future contracts. Another form of pressure is the threat of lost business. The customer must be able to develop an alternative source in order to remain credible. As the customers continue to improve, they will reach a point where all of their suppliers must be quality-focused producers. For example, when Texas Instruments tries to go beyond six-sigma capability, to achieve a seven-sigma or better, its suppliers must have the capability to improve as well. Texas Instruments' competition will continue to improve their capabilities. As a result, TI will not have a choice but to force its suppliers to change.

One of the larger issues that must be addressed is the cost versus benefits of converting to a TQM environment for the smaller companies. The costs will require up-front expenditure of resources for some unknown quantity of benefits that may only be realized in the long-term. The benefits can include increases in productivity, employee morale, adaptability and flexibility, competitive position, and

customer satisfaction. The benefits may also include decreases in cycle time, waste, rework, and the need for massive inspections and extensive management oversight. The small companies can achieve the same types of benefits as the larger companies. However, the marginal cost for each "unit" of benefit is greater for the small businesses. The larger companies have a greater base of resources to distribute the costs and risks. The small companies have very limited bases. For example, it will cost a small business more as a percentage of its income to achieve a 25 percent reduction in cycle time than it would for a larger company. As another example, if the small company invests in new manufacturing or test equipment, the costs must be distributed over a smaller base. It would also be difficult to justify the expenditure of ten thousand dollars for a piece of test equipment that may contribute only a small increase in quality and productivity for a product or service that represents only a small percentage of its overall business. It may not be cost effective for a small company to change. The potential benefits may not justify the costs and risks for the company.

To achieve its goal of long-term cost savings and quality improvement, the Apache program, the Product Manager and the prime contractors, may find it cost effective to make the investment in the small company to provide incentive for them to adopt a quality-focus approach to management and improve their capabilities with new up-to-date equipment and training. The Product Manager and the prime contractors may assume much of the costs and risks of converting the small company to a TQM environment. The end result may be to achieve cost savings, quality improvements, defect opportunity reductions, and a myriad of other benefits for the program. The investment may also result in creating a well-developed source for future programs. The Product Manager, in partnership with the prime

contractors will have to do a cost analysis to discover if the investment and potential benefits will justify the costs and risks involved.

F. SECTION FIVE - COMMUNICATIONS INFORMATION

1. Responses to the Questions

Open communications between customers and suppliers is a very important component of continuous process improvement. In response to the questions in section five, the quality experts offered a wide range of communications methods with their suppliers. Several of the smaller companies only communicate with their suppliers, providing feedback on quality issues only when a failure occurs. They claim it is a matter of resources, time, money and people, that restricts their ability to provide timely, continuous feedback.

The larger companies offer a wider range of feedback capabilities from in-house plant representatives to department quality surveys that monitor customer satisfaction ratings on a continuous basis. All the respondents agreed that open communications is an important tool for quality improvement. The companies that established long-term partnerships with their suppliers and customers, to include quality process certification, have discovered many advantages to open communication. The advantages can include faster response time to problem resolution, and an improved ability to quickly adapt to necessary process changes.

In response to the first question of the section, none of the companies interviewed was familiar with the specific quality improvement goals of the Apache Product Manager. The prime contractors had the best understanding of the Apache PM's quality improvement demands. Martin Marietta and McDonnell Douglas have established their own goals to meet their needs and capabilities. Annually, the prime contractors

communicate their quality improvement goals to their suppliers and vendors. Several of the larger subcontractors have also established set goals for quality improvement. The quality improvement goals and objectives are not necessarily directed towards improving the Apache Helicopter Program.

In response to the question about how the Apache PM can help encourage continuous process improvement and defect opportunity reduction, the respondents agreed that Apache PM can do more to help. Most of the respondents agreed with the suggestion that the Apache PM could offer to provide a team of quality experts to assist the smaller producers of critical components and services with their quality improvement efforts. Several of the quality experts agreed that in limited cases, the Apache PM could help improve quality by providing Government furnished equipment and machinery.

2. Analysis

The communications process between the customers and the suppliers is sound. The continuous feedback on the quality of the products and services has served as a mechanism for measuring the customer's satisfaction. The contractors and subcontractors are using the feedback to make the necessary adjustments to their quality control.

There is a lack of communications between the PM and the second-tier subcontractors and below. The separation between the different levels of contractors was created to ensure privacy of contract. However, as the representative of the ultimate customer, the PM must have the means to communicate his quality goals to the subcontractors that produce the critical components for his system. The PM must develop the means to communicate through the layers of subcontractors without interfering with the privacy of contract. The smaller companies have fewer resources available to develop intricate feedback processes for their suppliers.

As recommended by several of the quality managers interviewed, the PM and the prime contractors should sponsor a team of quality experts to provide training support for the smaller companies that do not have the resources available to assist their suppliers. The training should be tailored to fit the different size companies and specific field of manufacturing and service. The companies receiving the training and counseling must be able to relate to the subject.

The open lines of communications indicate that teamwork and cooperation are the driving force for continuous process improvement. The communication process is in place and should serve as the primary means for crossing the boundaries of functional barriers that exist between the many different organizations in the process.

G. CHAPTER SUMMARY

As indicated by the responses from the quality and product experts who contributed to this study, TQM is the management philosophy of choice for the mid- to large-size companies. The smaller companies have fewer resources available to them; therefore, their focus is more oriented on the near-term requirements and results. Less than 50 percent of the small, third-tier contractors have a formalized process for continuous improvement.

The systems and processes involved in the production of the Apache helicopter and its many component subsystems are highly technical and require complex materials and procedures to produce. The companies must have a system and management style that can successfully integrate the multitude of inputs and procedures to the production and assembly processes while maximizing the efficiency of the resources and materials used.

The adoption of the Total Quality Management philosophy has provided the means to control and improve the product and processes.

Companies are responding to the demands of their customers. The Government is demanding better quality from its contractors; therefore, every level of subcontractor must strive to achieve this goal, or risk losing business. The defense acquisition programs have been significantly reduced. Contractors are doing everything they can to improve their competitiveness. Contractors are investing more time and resources to help improve their suppliers' quality capabilities. Companies are improving their communication processes to provide their suppliers a better understanding of their quality requirements.

The processes and systems for long-term quality control and improvement are in place for a majority of the higher-tier companies. However, it will take time and resource investments to improve the lower-tier companies.

V. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

The current trend of acquisition reform, coupled with the pressures on the commercial markets to move to an integrated, quality-oriented, customer-supplier relationship is developing in a positive manner. The pressures to improve product quality include the demand for supplier quality process certifications, supplier-base reductions, and the increase in global competition. As a result, Total Quality Management has emerged as the management style of choice. The TQM philosophy is being implemented at all levels of industry. Customers are getting better at specifying what they want, and suppliers are getting better at meeting the customer demands. Contractors are developing well-defined long-term strategies. They have a clear vision for where they want to be and by when. It is evident by this study that those companies that fail to recognize the need to adopt a business operating environment that fosters quality improvement will have an extremely difficult time competing for contracts.

B. CONCLUSIONS

The quality and reliability of the Apache helicopter system and its component subsystems are currently within acceptable standards and meet contract specifications. The prime contractors and most of the second-tier contractors have well-developed quality control and quality improvement processes. However, there is plenty of room for improvement. Something must be done to increase the quality improvement efforts of the smaller, subtier contractors supporting DOD's major weapon systems development and productions.

Demands on the already limited resources of DOD are growing exponentially as the cost of technology multiplies and the need to replace the older systems arises. DOD must find ways to decrease costs associated with each weapon system's development, production, and operational support. In addition, the quality and reliability must dramatically increase. DOD can only afford to purchase a limited number of weapon systems. The limited number of systems must be able to do more than previous systems, and with greater accuracy. As demonstrated in Operations Desert Shield and Desert Storm, state-of-the-art weapons can make a decisive difference on the battlefield. The key is to win the war quickly and with limited friendly casualties. Modern weapon systems can accomplish this goal.

The entire weapon systems development and procurement process is undergoing dramatic changes in recent years. One of the key contributing factors has been the implementation of the practice of Total Quality Management and Continuous Process Improvement by contractors and Program Management Offices. TQM and CPI have proven to be the catalysts for reviving the quality competitiveness of American industries in the global market. The philosophy behind TQM has enabled many companies to decrease their costs and increase their quality capabilities to such a level that they have become world-class leaders in their field. This effort toward long-term quality improvement must continue. The process must be pushed down to the lowest levels of suppliers. It will take a long time and a lot of investment of resources to develop the lower-tier contractors. DOD, through the Product Managers and the prime contractors, must make a special effort to motivate the lower-tier contractors' quality control because their products and services are key to the overall system quality.

There are many risks involved in converting to a TQM environment. Not every company that has attempted TQM has been successful. If all the elements come together and the company is successful, the payoffs can be very generous. The benefits can include lower costs, higher profit margins, increased capability and flexibility, and faster cycle times. However, if the company cannot integrate all the elements, there can be serious repercussions on the company's ability to remain competitive.

Many prime contractors are taking the initiative to force their subcontractors to adopt a quality-oriented philosophy or lose their business. For many subcontractors it is a do-or-die predicament. The prime contractors are reducing their supplier-base and only retaining companies that add to their quality processes. Many of the subcontractors facing this situation are accepting risks and opting for change.

Second-tier contractors are working feverishly to become quality producers. They are often new to the ideas and practices of TQM, but they are making the organizational and cultural changes necessary to improve their capabilities. They are often still in the early stages of reducing and certifying their supplier-base. The second-tier subcontractors cite the lack of time, money, and people as the reasons for the slow pace of forcing their suppliers to change. They did, however, express long-term intentions to work with their suppliers to improve their quality processes.

Because of privity of contract and the lack of open communications with the Product Management Office, the subtier contractors do not always have a close association with the DOD programs their products support. Product Managers, and even the prime contractors, have very little influence on lower-tier subcontractors' operating environment. Market forces such as supplier-base reductions and mandatory quality process certifications may be the primary means to influence

the lower-tier contractors. The contractors must be able to choose their own rate of change. They are most familiar with their capabilities and resources and those of their suppliers.

C. RECOMMENDATIONS

After carefully studying the issues and problems addressed in this study, the author offers the following recommendations:

1. Market Forces

Allow the market forces to set the pace of change. The PM must allow the contractors the flexibility to monitor their own rate of quality improvement. The contractors have a better understanding of the risks and costs associated with the improvement process. As the customer demands for higher quality increases and the competition improve their capabilities, the defense contractors will expand their own capabilities to either stay with the competition, or to get ahead. They will provide the needed incentives or pressures on their suppliers in order to meet their needs.

Companies with poor quality and process control must take the necessary steps to improve, or risk losing business. In the long run, only quality-oriented companies will be able to compete for limited contracts. Even specialized companies, that serve as the sole-source for many of the more complex materials and services, must find ways to improve their quality and lower their costs. Many customers may find it is to their advantage to find new sources or develop their own internal capabilities. For national security purposes, the Government cannot allow certain critical domestic sources for specialized materials, components, and services to disappear. In these few cases, the Government must take the necessary steps to assist these sources improve their quality capabilities through mandates and financial assistance.

2. Become a Better Customer

The customer is the keystone to the whole process. The customer places the demands and is responsible to define the level of quality that is necessary to satisfy the demands. To become a world-class customer, DOD should consider the following recommendations:

- Develop a working relationship with the contractors that is based on trust and mutual support.
- Move away from the use of mass inspections and sampling. Focus the limited resources on designing quality into the product and the processes.
- Develop the means to certify the quality processes of the contractors and subcontractors. The certification can reduce the need for expensive oversight and unnecessary testing and sampling.
- Train key decision makers in the TQM process. Senior DOD acquisition leaders must have a full understanding of the benefits and barriers of TQM.
- Integrate the TQM process throughout the DOD acquisition community. There must be a standard that each agency can follow. The standard will also make it easier for the contractors to coordinate their requirements.
- Never accept the idea that a process or product is as good as it will ever get. Always try to make it better.

3. Continue Current Acquisition Reforms

DOD must continue to reduce the barriers to change. Through an integrative reform process, DOD and representatives of the defense industry should remove non-value-added policies, regulations, and contract requirements that place undue burden and cost on the procurement process.

DOD should continue giving the responsibility for quality back to the prime contractors. This increased responsibility should increase the market pressures on the lower-tier subcontractors to adopt a quality-oriented approach to management.

DOD must be willing to take bold steps to develop new ideas and implement innovative procedures to achieve long-term quality improvement and cost reductions.

4. Communicate Goals and Objectives for Change

a. Process Action Team

The Apache Helicopter PM should sponsor a Process Action Team (PAT) to address the problems and issues surrounding the need for long-term quality improvement at all levels of suppliers and manufacturers. The PAT should consist of representatives from all Government agencies with a stake in the process and representatives from the prime contractors and critical subtier contractors. The PAT should be guided by a quality expert to ensure they address the key issues and develop reasonable solutions.

The PAT should pay particular attention to the needs of the smaller subcontractors. The smaller subcontractors have the most trouble with adopting a TQM style process because of the limited resources available to them.

The PM must be able to describe his vision of the future for his product, as well as the particular quality improvement goals and objectives he hopes to achieve. On the other hand, the contractors should assess their own quality improvement capabilities, for now and in the future. The PAT should be able to combine the two requirements to develop reasonable solutions to the issues and problems.

b. Product Manager must Communicate Goals

The Product Manager must communicate his goals and objectives for continuous process improvement to all contractors and subcontractors. To maintain the rights of privity of contract, the PM must communicate his desires through the many levels of contractors.

The PM can use personal visits or memoranda to champion the need for quality improvement. Because of the limits on time and resources, the PM should focus his efforts on the producers of critical component and subsystem and those producers that present problems to the program.

c. Training Team

One possible solution would be for the PM to sponsor a training team of quality experts that can travel to the many contractors and subcontractors to introduce the concepts of the TQM processes. The training team could provide technical assistance to improve existing processes.

The subcontractors have many different needs. The team must have the flexibility to tailor its course to fit different needs and requirements of the potential audience. For example, the smaller subcontractors will probably only have limited exposure to the TQM concepts. Their needs will require basic hands-on application procedure rather than vague concepts and theories.

The team will most definitely need the support of the prime contractors not only to share the expenses, but also to open access to the subtier contractors.

Another method of defraying the cost associated with the mobile team could be to combine the efforts and resources of other program offices that share similar subcontractors. The joint project could benefit both parties for the long-term.

D. CHAPTER SUMMARY

This thesis has exposed several positive features of the quality improvement efforts of the contractors supporting the Apache Helicopter Program. One of the most important features is the fact that the contractors and second-tier subcontractors have well-developed, active quality control and

improvement processes in place. Their quality-oriented business attributes will greatly enhance the long-term capabilities and features of the program. Another propitious highlight is the effect that the DOD acquisition reform measures are having on the defense industry. The reform steps are changing old paradigms and causing a revolution in management and quality control. The responsibility for quality control is returning to the contractors. The reform processes will strengthen the Apache Product Manager's ability to manage the changes needed to improve his program in the long-term.

This thesis also highlights a number of negative aspects of the TQM practices of the contractors supporting the Apache Helicopter Program. The first negative feature is the fact that many of the critical, subtier contractors at the third-tier and below still have not adopted a business operating environment that fosters Continuous Process Improvement and quality control. To achieve long-term cost savings and quality improvements, every contractor, including the smaller contractors, must contribute by controlling their quality variations in the processes and allowing continuous improvement of all products and processes. Most of the smaller companies are changing too slowly or not at all. The lack of available resources, such as time, money, and people, is a primary excuse for many of the smaller contractors not to accept a TQM environment. The Apache PM must identify those companies that do not practice TQM, and determine whether or not they represent a critical component of the program or a potential problem. The Apache PM must concentrate his limited resources on improving those companies.

The Apache PM's shortage of resources, especially the lack of money, represents another negative feature noted in this thesis. Budgets are getting tighter every year. The Apache PM must be able to do more with less. The Apache PM must be able to influence the quality control efforts of those

non-TQM companies in an effective, low-cost process. The Apache PM can enhance the quality control efforts by becoming a better customer, continuing to develop the acquisition reform measures, taking steps to develop a method of communicating quality goals and objectives to all levels of contractors, and finally, allowing the natural market forces to set the pace of change. The Apache PM must make the investment now in order to achieve the desired results in the future.

E. RECOMMENDED FURTHER RESEARCH

The following areas warrant further research to extend the concepts and issues presented in the thesis:

1. Research DOD's TQM Policy Implementation

DOD has developed a TQM policy to improve the overall capabilities and efficiency of its operations and organizations. However, the policy has been filtered down to the various services and organizations with mixed enthusiasm and results. Many of the old paradigms still exist. The various DOD organizations have different quality standards and have achieved unequal levels of success with the TQM process. The differences have caused a multitude of problems and issues to be resolved. Follow-on research should be conducted to determine how DOD is handling those problems and issues.

2. Cost versus Benefit Analysis Model

Another follow-on research topic could be the development of a cost versus benefit analysis model. The model could be used to determine when the benefits of implementing a TQM process outweigh the costs of changing. To narrow the scope of the research topic, the model should concentrate on the issues concerning the small, subtier contractors. The small contractors have the most problems with determining when they should and must take the steps necessary to adopt a TQM approach to management. If the company has to pay more for

changing (the cost of new equipment, training, organizational restructuring) than it can expect to receive as a return on the investment (retaining old contracts, winning new contracts, and meeting its obligations to the company stakeholders) then it may not be worth the expenditure of resources.

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